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Summary of the Voyager Program

National Aeronautics and Space Administration
Office of Space Science and Applications

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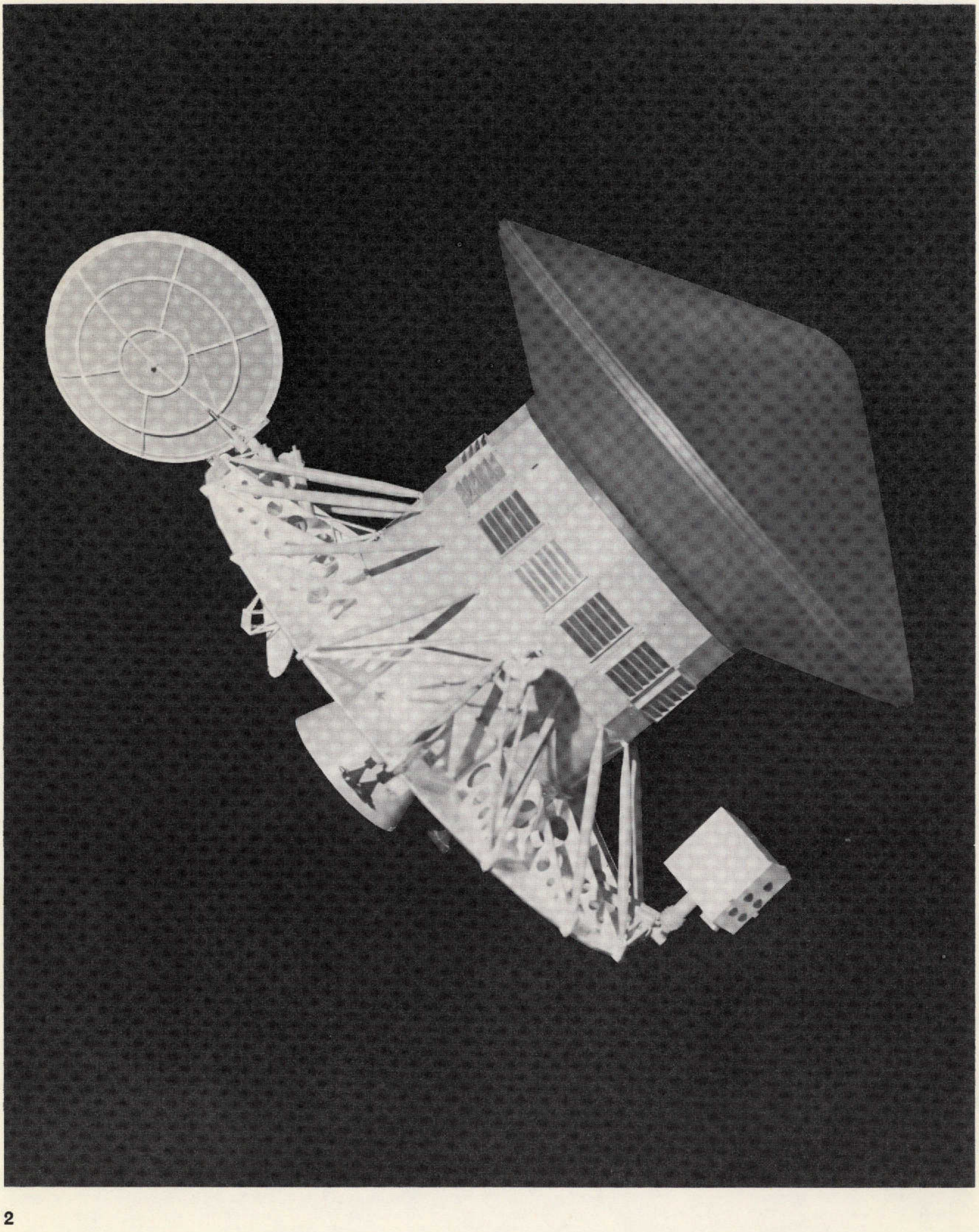
Foreword

The exploration of our solar system is one of the most exciting and scientifically rewarding pursuits of our time. Successes already achieved in the 1960s with unmanned spacecraft of limited weight and power—constrained by launch vehicles developed initially for other purposes—foretell the great work of exploration that lies ahead. Already man has been able to send instruments close to Venus and Mars, and to image one part of the Moon with a resolution down to features 0.5 mm in size.

With Voyager, the U.S. capability for planetary exploration will grow by several orders of magnitude. The launch vehicle for Voyager will be the awe-inspiring Saturn V, first created for manned lunar exploration in Project Apollo. When used for fully automated exploration, Saturn V will be able to place some 30 tons on a trajectory to Mars. The Voyager class of spacecraft, designed for this Saturn capability but drawing upon the experience gained with their smaller precursors, will in the 1970s add immeasurably to man's knowledge of the solar system—planets, their natural satellites, comets, and asteroids. Voyager could well be the means by which man first learns of extraterrestrial life.

HOMER E. NEWELL, Associate Administrator for
Space Science and Applications
National Aeronautics and Space Administration

December 1966



What Is Voyager?

Voyager is an unmanned planetary program using a new generation of scientific spacecraft, larger, heavier, and technically more advanced than any previously flown. These spacecraft will be launched in the 1970s by the world's largest booster rocket, the *Saturn V.*

Geared to explore much of the solar system, *Voyager* will first investigate the closest planets, Mars and Venus. Three primary objectives will shape the *Voyager* missions: to gain knowledge about the origin of the solar system; to gain knowledge about the origin of life; and to apply both to a better understanding of terrestrial life. In pursuit of these goals, *Voyager* will orbit, reconnoiter, and soft-land on the planets; search for forms of life; provide data on the physical, thermal, and chemical properties of the planets; and send back to Earth high-resolution photographs and an unprecedented volume of additional data.

Overlying these scientific goals will be a broader objective of retaining for the United States a clear primacy in exploring space for the benefit of all mankind.

We recommend planetary exploration as the most rewarding scientific objective for the 1970–1985 period.

—Space Science Board
National Academy of Sciences

The biological exploration of Mars is a scientific undertaking of the greatest validity and significance. Its realization will be a milestone in the history of human achievement. Its importance and the consequences for biology justify the highest priority among all scientific objectives in space—indeed in the space program as a whole.

—Recommendation of Exobiology Study
Conducted for Space Science Board
National Academy of Sciences

Scientific Questions About Mars and Venus

Because Mars has been studied from Earth since the beginning of recorded history, there is some knowledge of the planet. It is known that Mars has retained a thin atmosphere, evidently composed of nitrogen, argon, and carbon dioxide. Depending on latitude and season, surface temperatures range from a high of 70°F to a low of perhaps −95°F, which is a severe environment, somewhat ameliorated by a rotational period of 24 hr, 37 min. There is spectroscopic evidence of a slight amount of water vapor. The surface features of Mars have been mapped with a ground resolution of 65 mi, and down to approximately 2 mi in some areas scanned by *Mariner IV*.

However, many unanswered questions remain. The most frequent single scientific question is whether or not there is life on Mars. Much evidence suggests that it is at least possible and more probable than on any other planet but Earth.

There are other uncertainties:

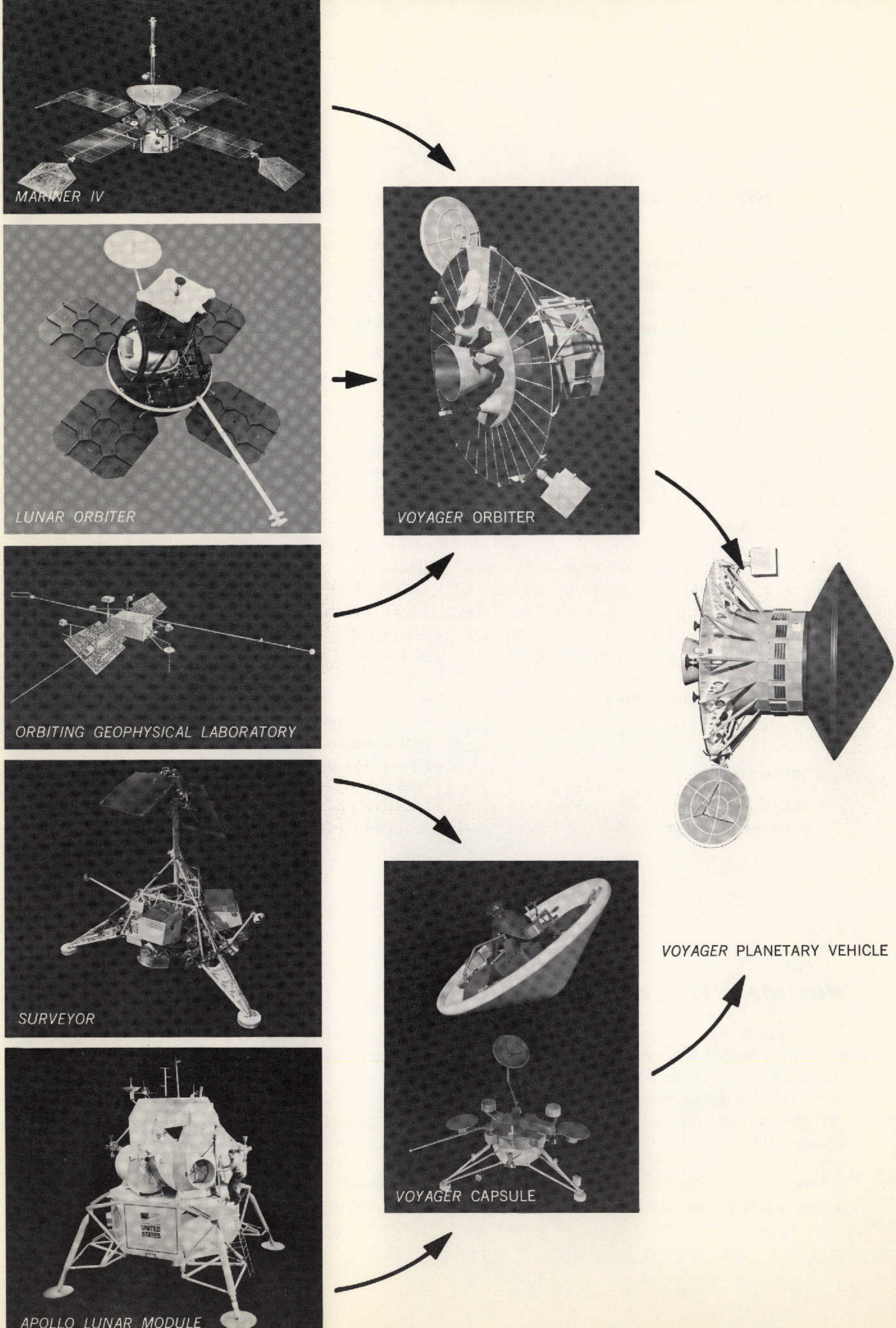
- What is the composition of the orange "desert" areas? And the adjoining darker surfaces?
- Are the white, seasonally varying polar caps composed of ice crystals?
- What causes the perplexing blue haze?
- Are the occasional, obscuring yellow clouds giant dust storms? And what is the composition of the white and blue clouds?
- Do the darker areas indicate the presence of organic activity?
- What causes the seasonal wave of darkening that, in the Martian spring, appears at the receding polar cap and moves toward and past the equator?

The major scientific unknowns of Venus equal or exceed those of Mars. Venus is so heavily shrouded in clouds that we cannot be sure that, as radar measurements suggest, it has a retrograde rotation of about 250 Earth days. The clouds are opaque and highly reflective, and the nature of their composition is uncertain. Much doubt exists regarding the composition and pressure of the atmosphere. There is a radiometric indication of surface temperatures above 600°F—far too high at the surface for terrestrial life forms, if the reading is correct. There are radar indications of at least one high, continental-scale mountain range; and there is a perplexing similarity of apparent temperatures on the sunlit and dark sides.

Why Mars First?

Although Venus is of approximately equal accessibility and poses as many scientific questions, the first *Voyager* missions are planned for Mars. One reason for this decision is that the high surface temperatures on Venus make the existence of extraterrestrial life less likely than on Mars.

Other considerations in the *Voyager* scheduling are based on the fact that the thin, normally transparent Martian atmosphere is conducive to the detailed scanning of its surface features from orbit, and that manned landings on Mars will someday be possible; according to present data, they may not be possible on Venus. Finally, the experience gained in Mars missions, in the technology of automated vehicles and in the design of scientific instruments, will be directly helpful in the exploration of Venus and other, more difficult planets.

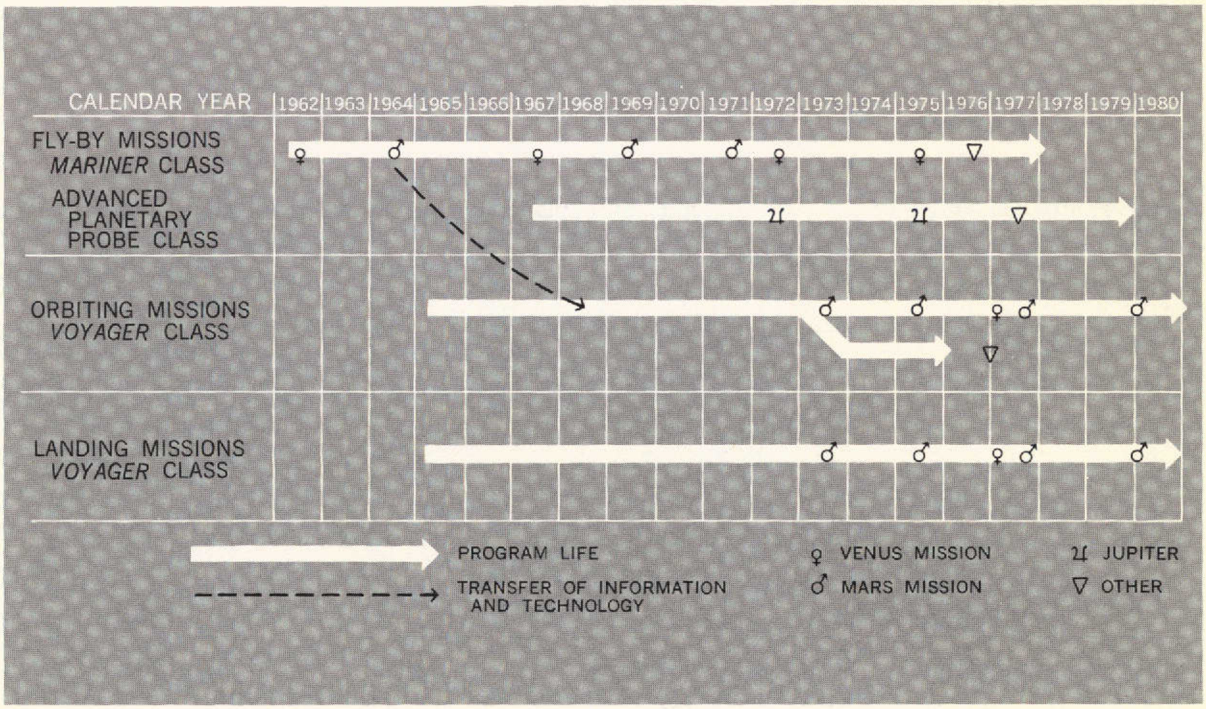

MARINER IV
LUNAR ORBITER
ORBITING GEOPHYSICAL LABORATORY
SURVEYOR
APOLLO LUNAR MODULE
UNITED STATES
VOYAGER ORBITER
VOYAGER CAPSULE
VOYAGER PLANETARY VEHICLE

Voyager's Technological Inheritance

Despite *Voyager's* impressive size and advanced capabilities, it is soundly based on technical knowledge gained from previous flight systems, which include the *Mariner,* man's first successful planetary spacecraft; the *Lunar Orbiter,* which pioneered in orbiting a distant celestial object; and the automated Earth satellites, such as the *Orbiting Geophysical Laboratory,* that have provided experience in space platforms designed to make sensitive scientific measurements from orbit. *Voyager* will use many technological features developed on earlier spacecraft: solar cells for power, omnidirectional and high-gain antennas; an on-board central computer; attitude stabilization; the use of Canopus as a reference; trajectory-correction maneuvers; and temperature-control techniques.

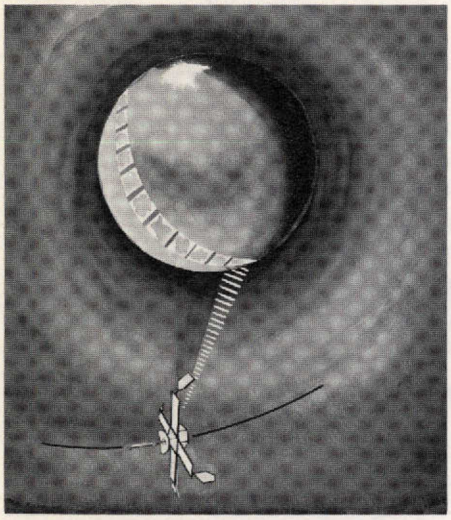
Voyager will gain from *Surveyor* and *Apollo* the technique for soft-landing on a planet through automatic, closed-loop mechanisms. *Surveyor's* radar altimeter and doppler velocity sensor, used in conjunction with a computer and autopilot, is adaptable for the *Voyager* landing capsules. Project *Apollo* may also lend some of its rocket motors and other spacecraft components, as well as its technology for atmospheric entry.

Evolution and development of planetary missions

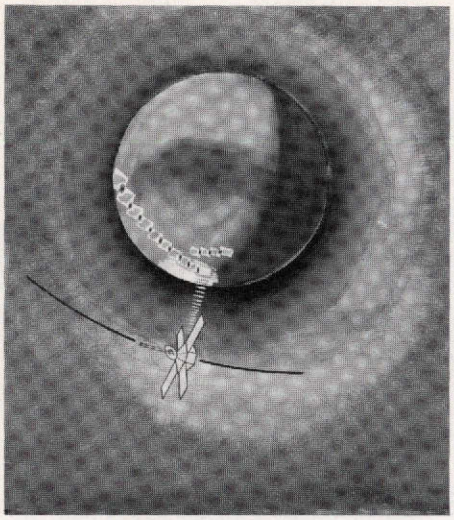


Following the *Voyager* missions to Mars, starting in 1973, will be the *Voyager* missions to Venus, starting in 1977. In the 1980s, *Voyagers* will be used to explore the outer planets. It is important to note that, during the period in which the large *Voyager* system is first used for Mars, there is a continuing need for *Mariner*-class spacecraft for precursor missions to Venus and to the outer planets. Within the restrictions of launch opportunities and the lead times needed to develop and test spacecraft, the sequence of missions shown remains highly flexible. Scientific and technical information gained from previous flights feed into subsequent missions.

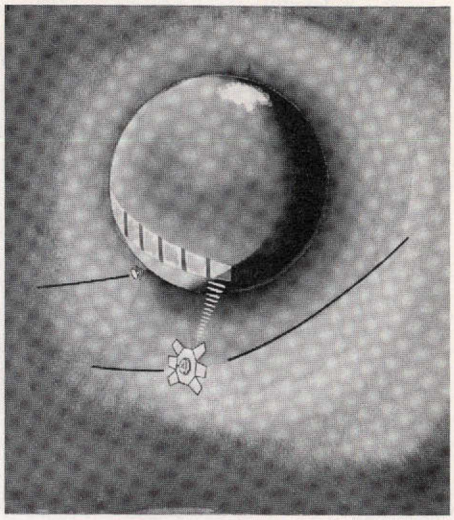
A Plan for Exploration of Mars



Mariner IV (1964): Fly-by



Mariner 1969: Fly-by



Mariner 1971: Fly-by With Atmospheric Probe

Scientific Objectives

Photograph approximately 1% of surface

Investigate atmospheric pressure profile

Make field and particle measurements

Photograph entire planet during approach

Photograph 10% of surface at high resolution

Investigate pressure and composition of atmosphere

Investigate surface temperature

Direct measurement of atmospheric profile: pressure, temperature, density, and composition

Direct measurement of surface pressure and temperature

Photograph additional 10% of surface at high resolution

Technical Advances

Fly-by of Mars

Communications across over 215 million miles

Digital photographic techniques

Canopus as celestial reference

Advanced scientific instrumentation

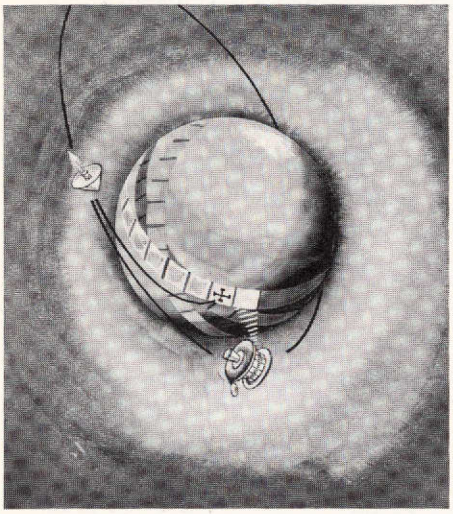
Increase of communications bit rate to 66⅔ bits/sec

Retrieval from Mars of more than 10^8 total bits

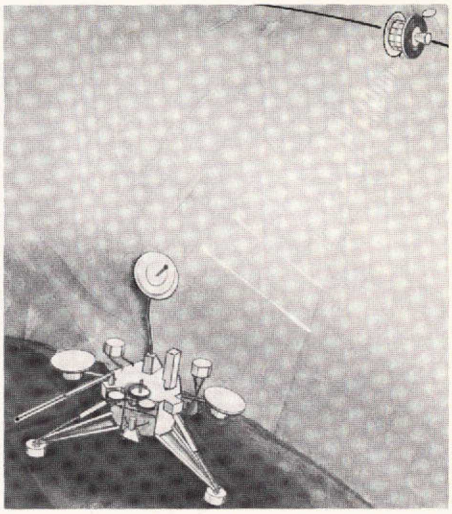
Demonstration of sterilization techniques

Demonstration of capsule-delivery techniques

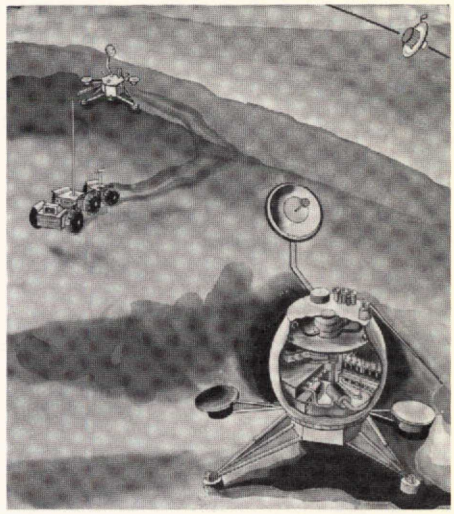
Demonstration of relay telemetry techniques



Voyager 1973: Orbiter and Lander



Voyager 1975: Orbiter and Lander



Voyager 1977/1979: Orbiter and Lander

Make selected spectroscopic and visual surveys

Make exploratory measurements on surface

Investigate biological environment

Investigate diurnal variations on surface

Observe seasonal changes from orbit

Development of orbital operations

Development of landing technology

Communications rate of 15,000 bits/sec from orbit

Communications rate of 600 bits/sec from Martian surface

Make additional spectroscopic and visual surveys

Make physical and chemical surface measurements

Perform biological experiments

Investigate seasonal changes on surface

Use of radioisotope power

Introduction of automatic programming and control

Make spectroscopic and visual studies of specific areas

Perform detailed surface studies in areas of high interest

Perform specific biological experiments

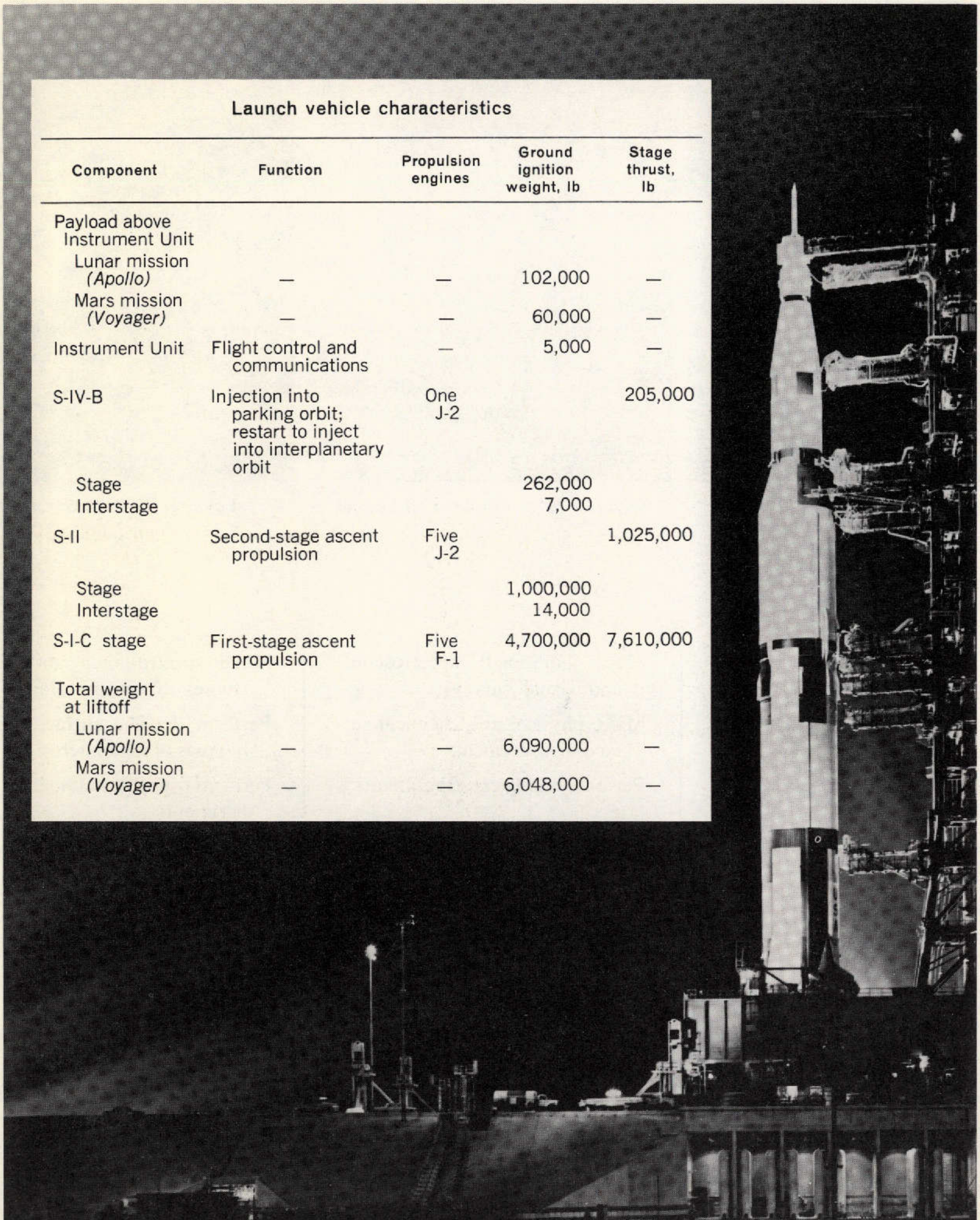
Investigate meteorology of Mars

Use of automated laboratory

Introduction of mobility on surface

Launch vehicle characteristics

Component	Function	Propulsion engines	Ground ignition weight, lb	Stage thrust, lb
Payload above Instrument Unit				
Lunar mission *(Apollo)*	—	—	102,000	—
Mars mission *(Voyager)*	—	—	60,000	—
Instrument Unit	Flight control and communications	—	5,000	—
S-IV-B	Injection into parking orbit; restart to inject into interplanetary orbit	One J-2		205,000
Stage			262,000	
Interstage			7,000	
S-II	Second-stage ascent propulsion	Five J-2		1,025,000
Stage			1,000,000	
Interstage			14,000	
S-I-C stage	First-stage ascent propulsion	Five F-1	4,700,000	7,610,000
Total weight at liftoff				
Lunar mission *(Apollo)*	—	—	6,090,000	—
Mars mission *(Voyager)*	—	—	6,048,000	—

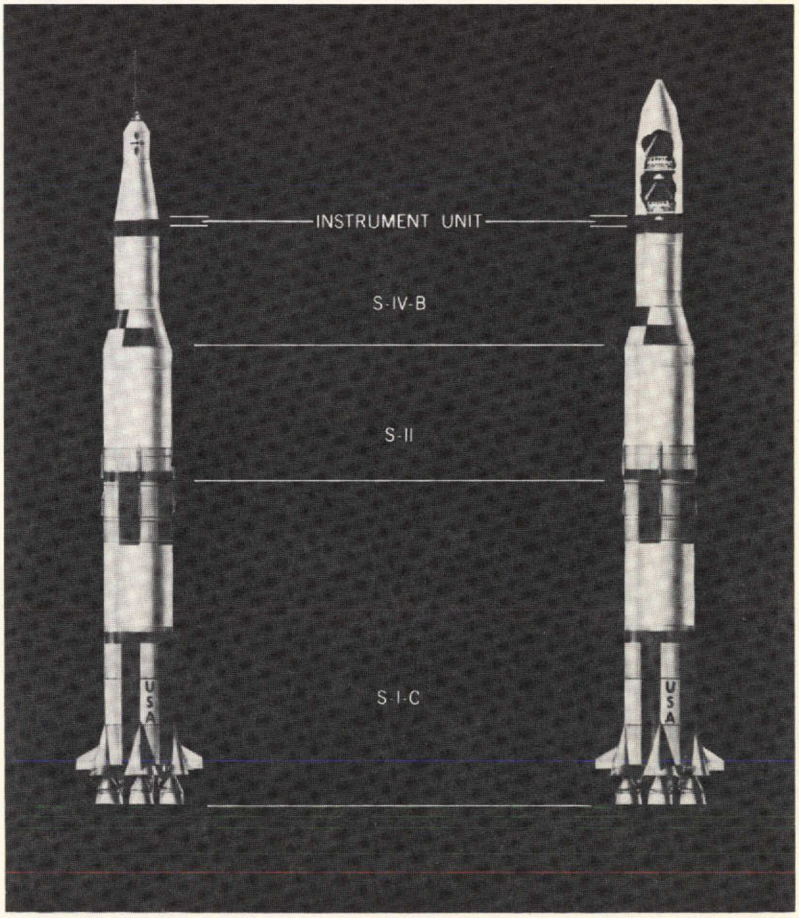


Voyager Launch Vehicle: Saturn V

The *Voyager* launch vehicle will be *Saturn V*, the three-stage vehicle developed for Project *Apollo*. It will have the same configuration except for a new nose fairing and shroud above the Instrument Unit. At each launch, a single *Saturn V* will carry two separate planetary vehicles weighing as much as 12 tons each, plus their necessary adapters, shrouds, and nose fairing. A spacecraft diameter of up to 20 ft can be accommodated. The launch vehicles will be essentially identical with those used in Project *Apollo*, though some simplifications over man-rated versions may be possible. The difference in liftoff weights for the two missions (see table on facing page) reflect the higher velocity requirements of Mars trajectories.

In addition to providing the necessary velocity and directional guidance, *Saturn V* will relay information about the planetary vehicles and will provide signals for separation events. Although the flight will be controlled automatically by on-board equipment, there will be provision for ground backup commands.

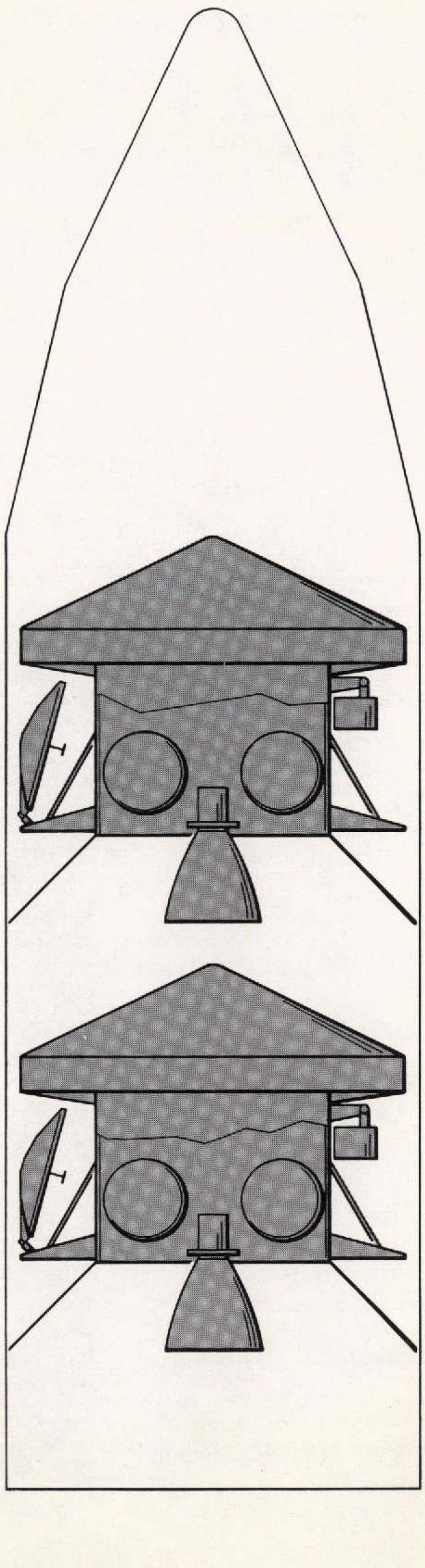
Assembly, checkout, and launch of *Voyager* will be conducted at Launch Complex 39, Kennedy Spacecraft Center. For Mars missions in the 1970s, a launch period of 25 days or longer is available at each opportunity, with daily launch windows of at least 1 hr.



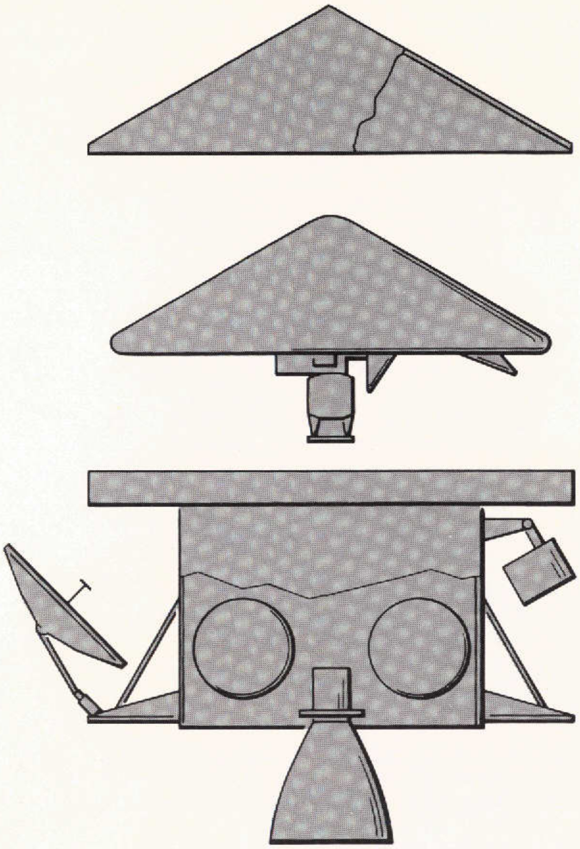
Saturn V vehicle configurations: *Apollo* at left; *Voyager* at right.

The Planetary Vehicle

Two independent planetary vehicles, mounted in tandem, will ride atop the *Saturn V*. Although they will separate from the third stage in close sequence, differing course corrections will separate their arrival times at Mars by as much as 10 days.



Each launch vehicle carries two planetary vehicles in tandem.



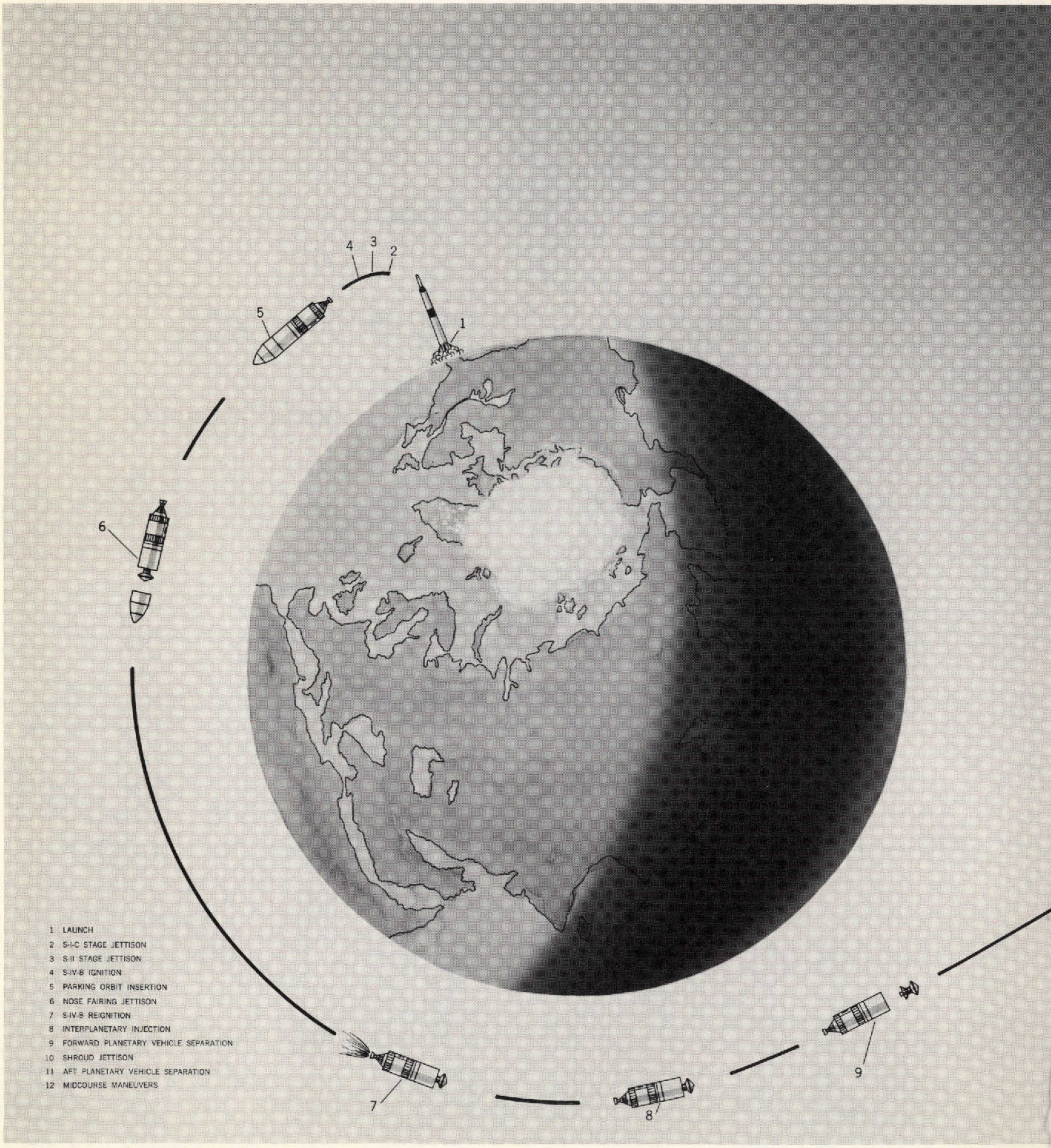
Major parts of one planetary vehicle

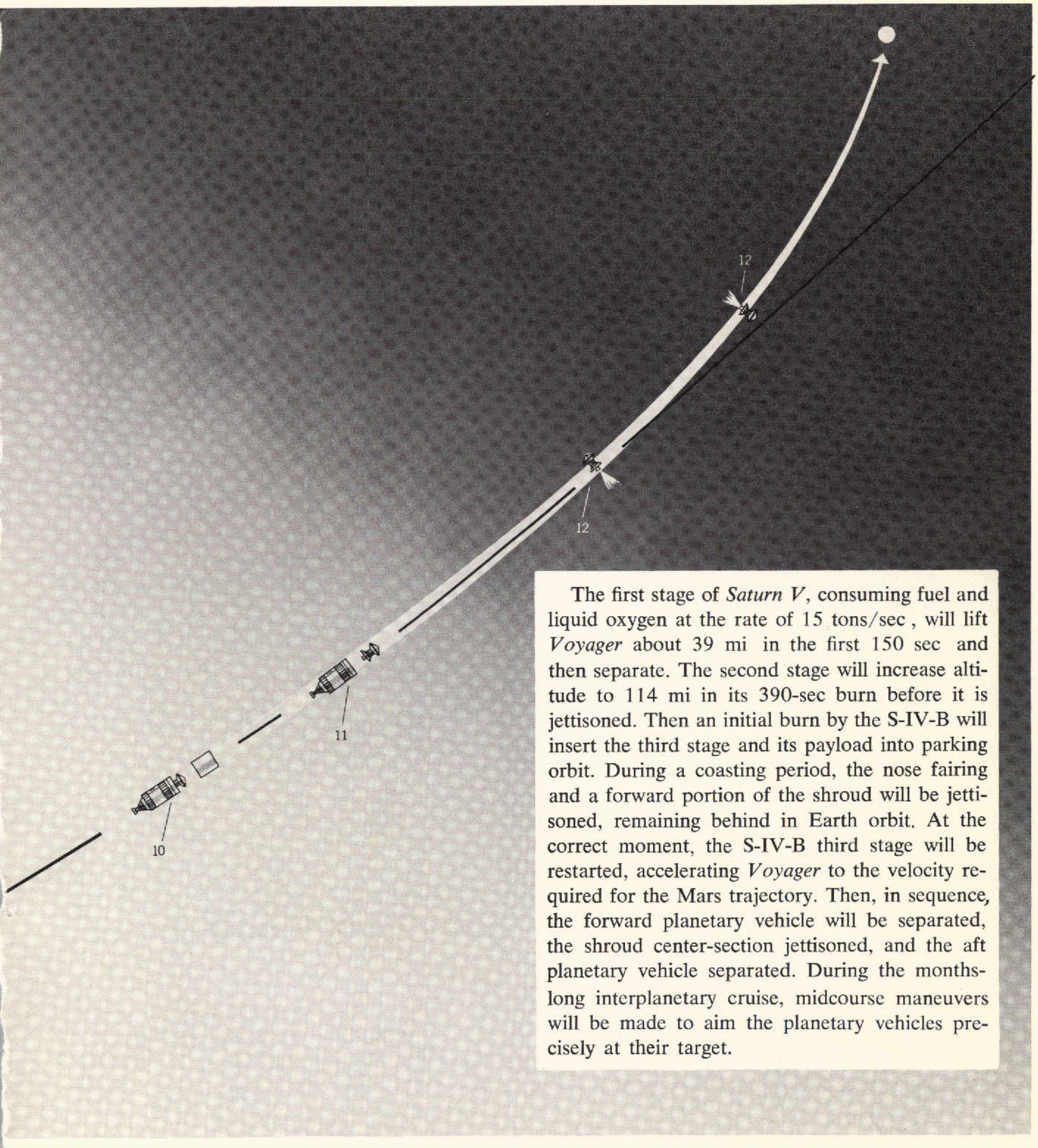
Overall *Voyager* weight breakdown in pounds

Characteristic	Baseline 1973	Typical growth potential 1975	1977/1979
Spacecraft bus/orbiter	2,500	2,500	2,500
Capsule	5,000	6,000	7,000
Propulsion	13,000	14,000	15,000
Total (one planetary vehicle)	20,500	22,500	24,500
Net injection weight (two planetary vehicles)	41,000	45,000	49,000
Shroud/adapter	9,300	9,300	9,300
Project contingency	5,000	3,700	2,700
Gross injected weight	55,300	58,000	61,000

Weight allocations currently planned for the initial *Voyager* mission to Mars in 1973 are shown in the table. Each planetary vehicle will weigh 20,500 lb, with 2,500 lb assigned to the orbiter and 5,000 lb to the capsule. At this point in design, allocated weights are 5,000 lb below the *Saturn V* capability. For launches after 1973, the launch-vehicle capability will probably increase, and the need for a weight-contingency allocation will decrease. Consequently, it is expected that more weight will be available for post-1973 missions, most of which will be allocated to the capsule.

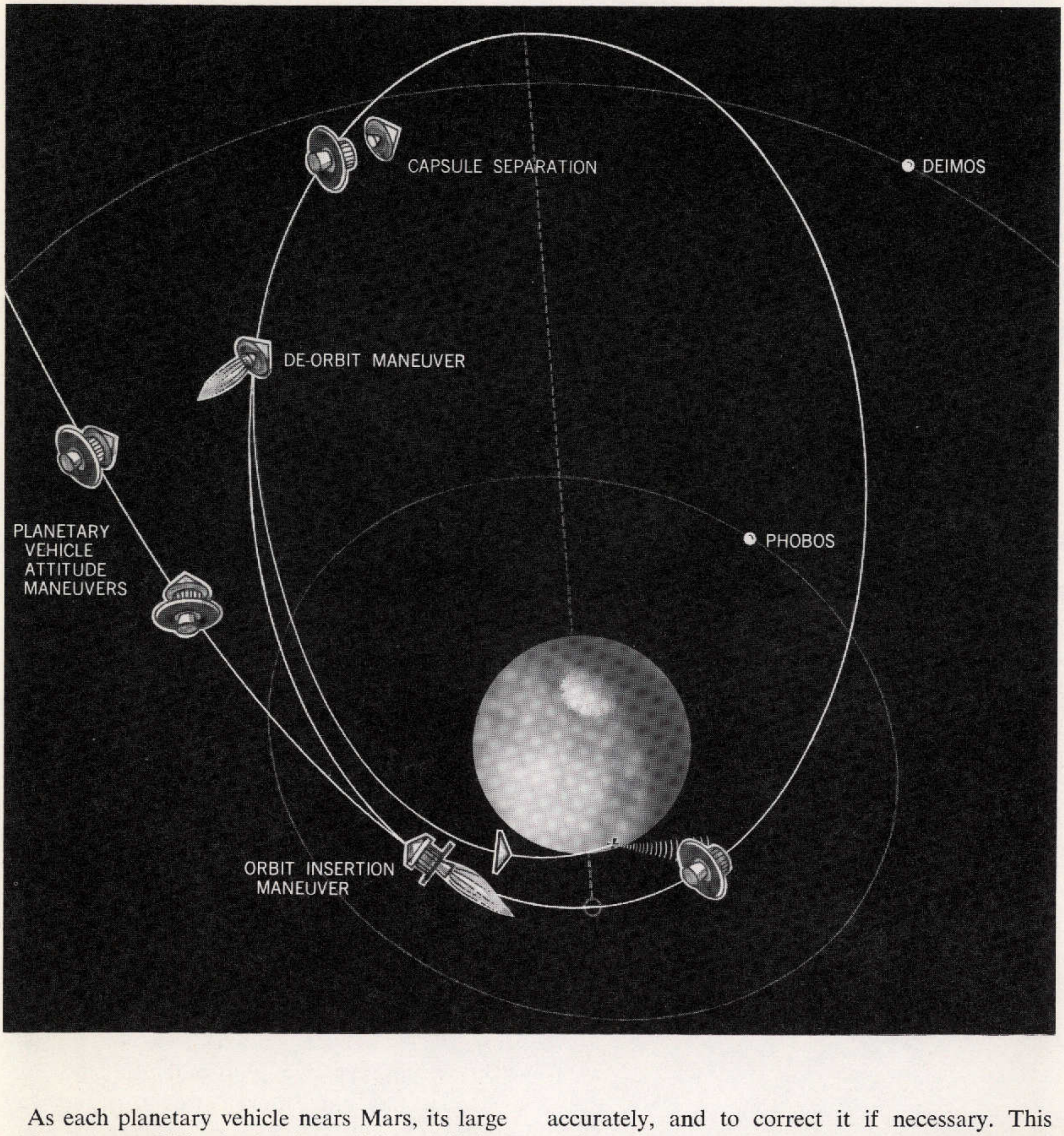
Voyager Launch Profile





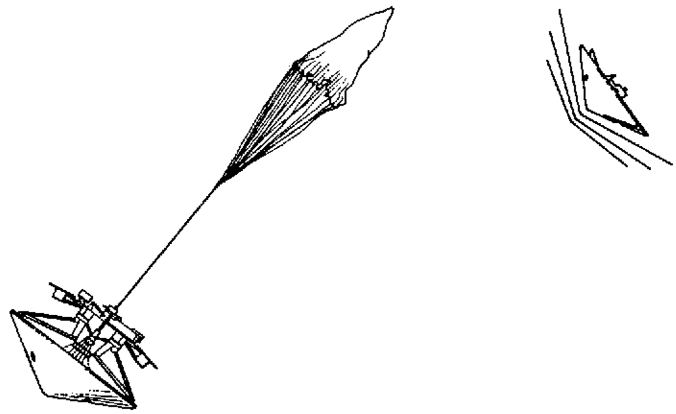
The first stage of *Saturn V*, consuming fuel and liquid oxygen at the rate of 15 tons/sec , will lift *Voyager* about 39 mi in the first 150 sec and then separate. The second stage will increase altitude to 114 mi in its 390-sec burn before it is jettisoned. Then an initial burn by the S-IV-B will insert the third stage and its payload into parking orbit. During a coasting period, the nose fairing and a forward portion of the shroud will be jettisoned, remaining behind in Earth orbit. At the correct moment, the S-IV-B third stage will be restarted, accelerating *Voyager* to the velocity required for the Mars trajectory. Then, in sequence, the forward planetary vehicle will be separated, the shroud center-section jettisoned, and the aft planetary vehicle separated. During the months-long interplanetary cruise, midcourse maneuvers will be made to aim the planetary vehicles precisely at their target.

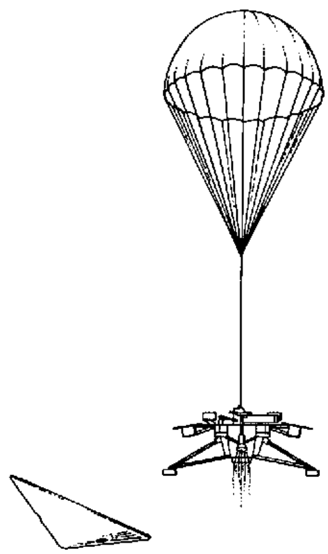
Orbital Operations and Capsule Release

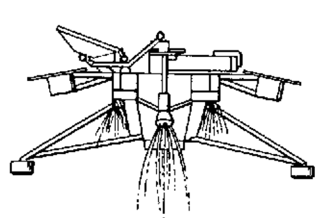


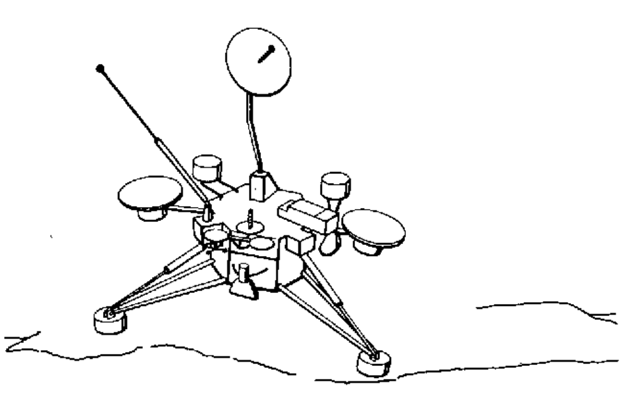
As each planetary vehicle nears Mars, its large rocket motor will be fired to insert it into a highly elliptical planetary orbit. Since velocity change required is on the order of 6,500 ft/sec, a large amount of propellant is needed. For several days, the vehicle will be tracked to determine its orbit accurately, and to correct it if necessary. This period may be extended several weeks to permit surveillance of possible landing sites for the capsule, which will be separated for its descent to the Martian surface. The orbiting spacecraft is designed to make observations for as long as 2 years.

Capsule Descent to the Surface









After separation, the capsule will orient itself in the correct attitude and, when it is far enough away from the orbiter, fire a solid retrorocket motor. This will slow it sufficiently to put it on a shallow flight path into the Martian atmosphere. At the time it enters the atmosphere, capsule speed will be between 12,000 and 15,000 ft/sec. Entering a long, shallow flight path, it will be slowed by aerodynamic drag to some 400 to 1,000 ft/sec at an altitude of about 15,000 ft. At this point, terminal deceleration will be provided by a rocket propulsion system, perhaps in conjunction with a parachute. The descent retropropulsion, controlled by radar, will decrease speed virtually to zero about 10 ft above the surface, and the capsule will drop softly to the ground.

During entry, the capsule will transmit measurements of the atmospheric environment, and television pictures of the Martian surface. After landing, the surface laboratory will be activated to take pictures and perform automated experiments, transmitting data to Earth either directly or by relay via the orbiter.

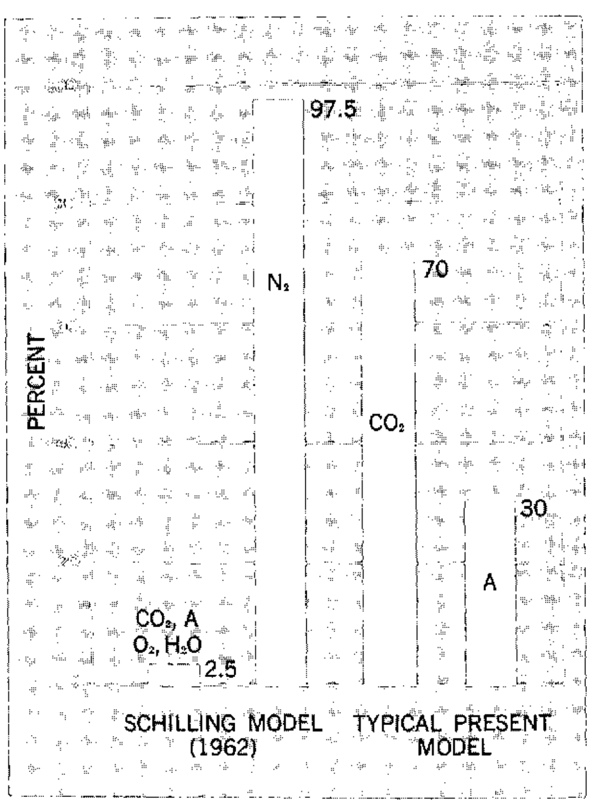
What We Know About the Martian Atmosphere

During the last decade, increased knowledge of the Martian atmosphere has greatly influenced the design of Mars missions. The earliest modern estimate of Martian surface pressure, made by Lyot in 1929, was 18 mb, a tenuous atmosphere when compared to Earth's surface pressure of 1,000 mb. In the late 1940s and early 1950s, this estimate was updated by the photometric and polarimetric observations of Dollfuss and de Vaucouleurs, who estimated a surface pressure range of 81 to 89 mb. Subsequent calculations by Schilling, published in 1962, expanded this range to 41 to 133 mb.

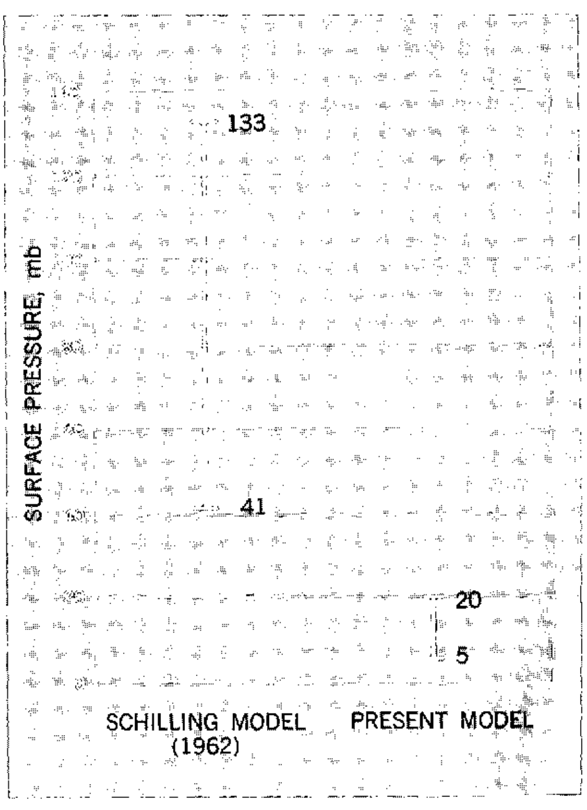
Using the latest spectroscopic technique, though based on just one photographic plate, the surface pressure of Mars was estimated in 1963 to be in the range of 10 to 40 mb. The results of the *Mariner IV* occultation experiment, conducted in 1965, further lowered the estimate of the surface pressure. Extensive ground-based spectroscopic observations in 1964 and 1965 agreed with these results. Present estimates indicate that the most probable surface pressure is in the range of 5 to 20 mb.

Other characteristics of the atmosphere, consistent with this range of surface pressures, are scale heights (proportional pressure profiles) of from 3 to 9 mi, and a composition that is approximately 70% carbon dioxide. Recent speculation has suggested that the surface winds on Mars may be extremely high, perhaps 250 ft/sec.

Composition history



Surface pressure history



The Effect of Martian Atmosphere on Voyager

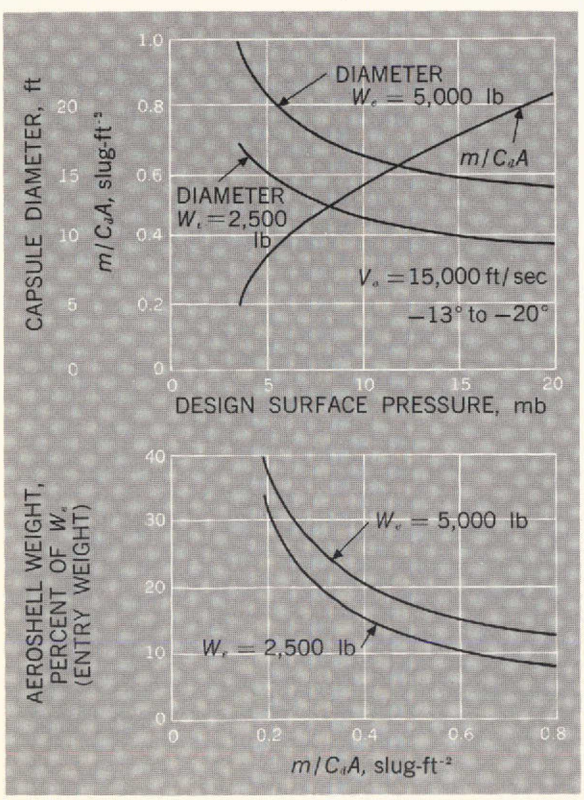
The lowering of the estimated Martian surface pressure has modified the techniques planned for landing a scientific payload. Even with the thin atmosphere anticipated, aerodynamic braking is still the most efficient means of slowing down a capsule entering at high speed. There are two means available for compensating for the lessened atmospheric drag: lowering the capsule ballistic coefficient (essentially the ratio of weight to diameter) and lengthening the flight path in the atmosphere.

Voyager will use both techniques. Capsules up to nearly 20 ft in diameter can be packaged in the *Saturn V* shroud; the flight path out of orbit will be held to the shallow angle of 15 to 19° by accurate entry-angle control.

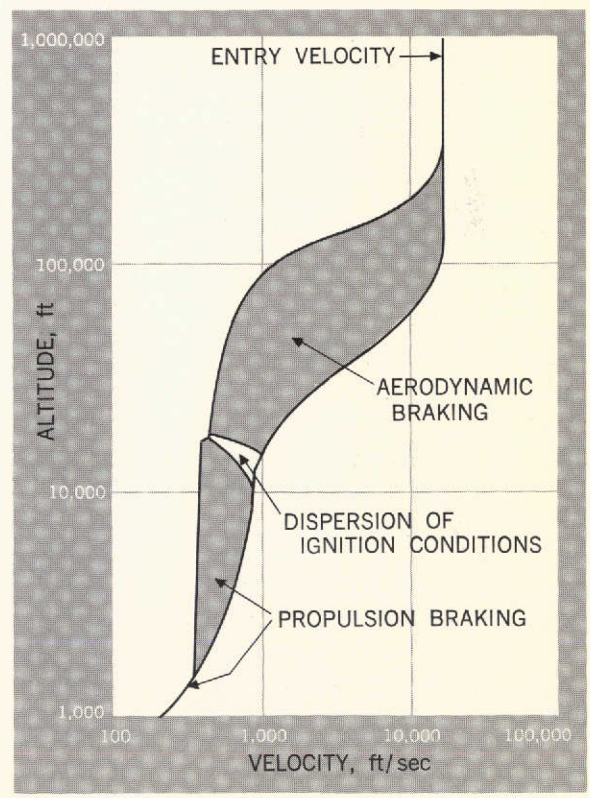
These techniques will retard the capsule from 15,000 to 1,000 ft/sec; further reduction to only a few feet per second is needed for soft-landing. Retropropulsion and parachute decelerators probably will be used during low-speed flight, with retropropulsion as the final part of descent. Soft-landing a substantial payload, and counteracting the effect of possible high surface winds are dual advantages obtained by such use of retropropulsion.

The *Voyager* lander will be designed for the full range of known atmospheric possibilities. Terminal propulsion, for example, will be designed to accommodate a whole spectrum of velocity/altitude combinations resulting from the aerodynamic braking. Data from *Mariners 1969* and *1971* can be applied to the verification of design assumptions.

Effect of surface pressure



Trajectory envelope for 5- to 20-mb atmosphere



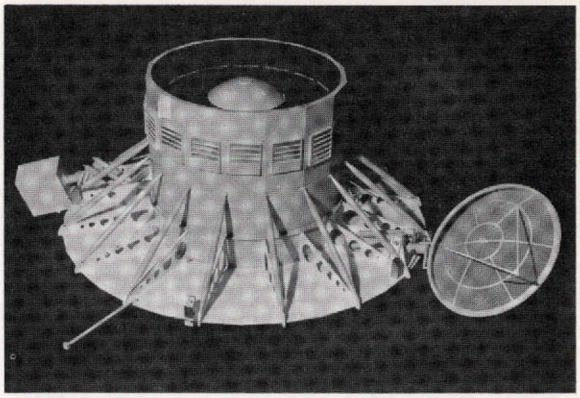
Characteristics of the Orbiter

The orbiter is designed to accomplish the transit to Mars, deliver the science payload and capsule into orbit, and then to provide a major capability for orbital operations and scientific experimentation. It will release the capsule at a predetermined location in orbit, and will provide a relay for capsule data and surveillance of capsule landing sites. The technical approach planned will develop a standard spacecraft system; science subsystem will incorporate planned design changes.

Three-axis attitude stabilization will be used with the Sun and Canopus as references. Power will be derived from panels of solar cells during Sun-stabilized mission phases. The solar cell array will have an area of about 250 square feet, with an output in Mars orbit that will vary from 1,000 to 800 w as Mars distance from the Sun varies. Rechargeable batteries with a capacity of 3,000 to 4,000 w-hr will be used for maneuvers.

A two-way communications system will provide telemetry to Earth; commands to the orbiter; and Earth-based tracking of angular position, doppler velocity, and ranging for orbit determination. An orbiter-to-capsule relay link will be available for use after capsule separation. A hard-line connection before separation will provide pre-separation capsule checkout and command. On-board equipment will include an S-band power amplifier with an output of 50 to 100 w; a 6- to 9-ft-diameter, steerable, high-gain antenna; and associated equipment. Data rates of 8,000 to 15,000 bits/sec and data storage on the order of 10^9 bits will be provided within the standardized design. In addition, data compression may be employed within the science subsystem. An on-board central computer and sequencer will provide automatic control for the nominal mission. Ground commands will be used to establish trajectory correction maneuver parameters or to alter the nominal flight sequence.

The orbiter will perform several propulsive maneuvers. During the flight to Mars, time-of-arrival and aiming point adjustments will be made. An orbit insertion maneuver will provide Mars



orbits with periapsis altitudes as low as 700 mi and periods of 6 to 12 hr; a wide selection of orbit plane inclinations to the Mars equator will be available. In Mars orbit, trim maneuvers will be made, providing a broader ability to observe various locations. Propulsion equipment for these maneuvers will weigh about 13,000 lb and will produce a total velocity increment of about 6,500 ft/sec. Two probable equipment sources are a modification of the *Apollo Lunar Module* descent engine, and the *Minuteman* Wing 6 second stage with separate monopropellant hydrazine engines for midcourse corrections.

Advanced technologies represented include techniques for data coding and compression; relay of capsule communications; large, steerable antennas; and long-life rechargeable batteries. Estimated weights, in pounds, for the major orbiter subsystems are given below.

Orbiter		2,300
Engineering mechanics*	775	
Telecommunications	340	
Guidance and control	250	
Power	535	
Science	400	
Contingency		200
Total (excluding propulsion)		2,500

*Structure, thermal control, cabling, and mechanisms.

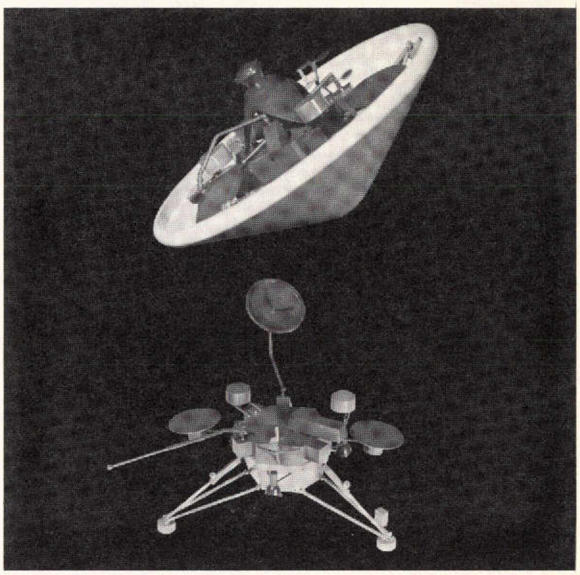
Characteristics of the Capsule

The *Voyager* capsule is composed of the capsule bus and surface laboratory systems. The capsule bus system is composed of pre-entry equipment (sterilization canister, adapter, de-orbit motor, and all other equipment that does not enter the atmosphere with the lander), and the entry and landing equipment (aeroshell, structure, parachute, and retropropulsion). The surface laboratory system includes the scientific instruments for operations on the planet's surface and support equipment (power, communications, etc.). As knowledge of the Martian environment is improved, as launch vehicle performance is increased, and with the availability of current weight-contingency allowances, it is expected that the weight of the surface laboratory can increase. Where possible, the capsule bus system will be designed to handle these increases without major change. Thus, the only changes expected from one launch opportunity to another will be to the surface laboratory system and its scientific payload.

The capsule will be decelerated by a combination of aerodynamic drag, parachute, and retropropulsion. Its ballistic coefficient will be about 0.3 slug/ft^2. Maximum entry velocity will be 15,000 ft/sec; the entry angle will be 15 to 19°, $\pm 1°$. A solid-fuel rocket will be used for the de-orbit motor. The retrorockets for soft-landing may be dual-propellant N_2O_4/UDMH engines. Velocity at ignition of the retrosystem will be between 400 and 1,000 ft/sec at an altitude of 10,000 to 20,000 ft, depending upon atmospheric conditions.

Capsule communications will be direct to Earth and relay via the orbiter. The relay rate will be as high as 50,000 to 200,000 bits/sec; direct communications will be about 600 bits/sec. Battery power may be used on early *Voyager* missions; it will be replaced by radioisotope thermoelectric generators (RTG) to provide the long lifetimes eventually needed.

Advanced technologies in the capsule will include sterilization, relay communications, RTG power, sample collection devices, and techniques for leveling and orienting the surface laboratory system. Estimated weights, in pounds, for these systems and subsystems are given for a possible 1973 design and are shown below.



Caspule bus			3,140
Pre-entry equipment		1,275	
Engineering mechanics*	860		
De-orbit propulsion	415		
Entry and landing equipment		1,865	
Engineering mechanics*	1,015		
Telecommunications	15		
Guidance and control	180		
Power	90		
Propulsion	565		
Surface laboratory			860
Engineering mechanics*	250		
Telecommunications	70		
Guidance and control	25		
Power	215		
Science	300		
Contingency			1,000
Total			5,000

*Structure, thermal control, cabling, and mechanisms.

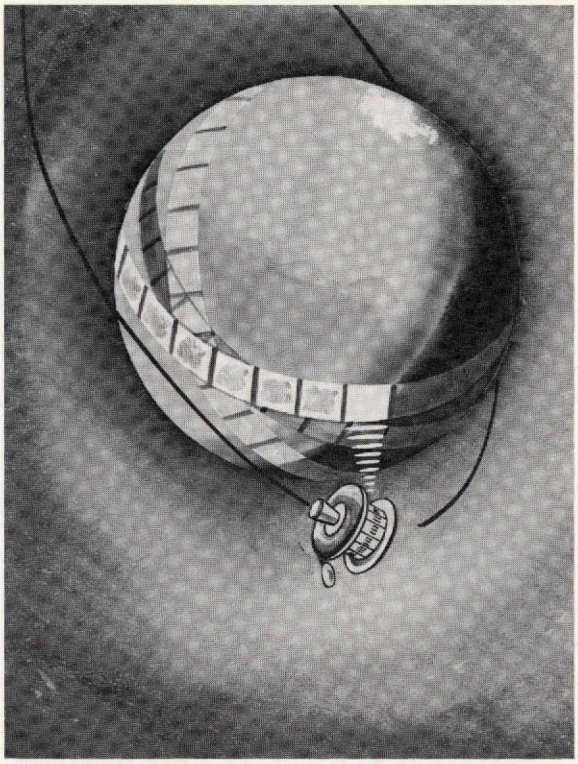
Scientific Explorations From Orbit

The scientific exploration of Mars will require the correlation of remote observations made from orbit with direct measurements made in the atmosphere and on the surface. The remote observations will provide large-scale survey measurements of the planet's physical characteristics. Observations made from a spacecraft in orbit about a planet are a natural evolution from observations made from a fly-by spacecraft. The orbiter has the advantage of observing over a prolonged period of time, thus permitting the study of seasonal effects, and scanning large areas of the planetary surface during a single mission. Orbital observations also provide the information needed for the selection of suitable landing zones for a surface laboratory system.

Experiments from orbit will probably include:

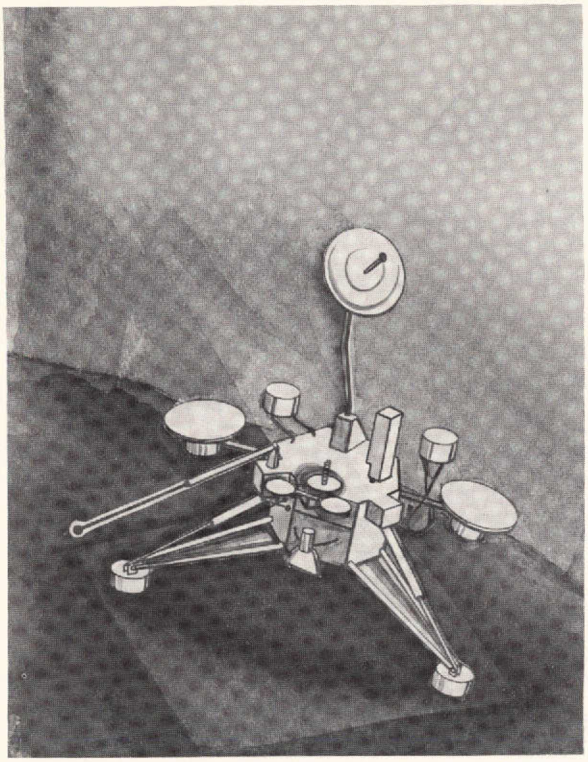
(1) *Planetary studies.* These will consist of gravitational measurements, mapping of visible and infrared light, topography, seasonal and diurnal variations, gamma ray and infrared spectroscopy, and magnetic-field measurements.

(2) *Atmospheric and environmental studies.* These will consist of ionosphere sounding, airglow studies, measurement of cosmic and solar radiation, atmospheric composition and distribution, circulation patterns, and meteorology.



The types of instruments carried in orbit will include imaging devices (film or television cameras), various spectrometers (infrared, ultraviolet, and gamma ray), microwave and infrared radiometers, ionospheric sounders, polarimeters, and instruments for measuring particles and fields.

Scientific Investigations During Descent and on Surface



Among the most valuable of *Voyager's* accomplishments will be the direct measurements made in the atmosphere and on the surface of Mars. They will be vital to the search for extraterrestrial life, and will significantly increase man's understanding of the planet.

Descent experiments will include atmospheric pressure, density, temperature profile, scale height, atmospheric composition, and topographic studies of the surface. Probable instrumentation will include television cameras, accelerometers, pressure transducers, temperature probes, mass spectrometers, and shock-layer radiometers.

Soft-landed on Mars, the surface laboratory system will acquire data on the physical, chemical, and biological environment. The areas of early experimentation on the surface will probably include:

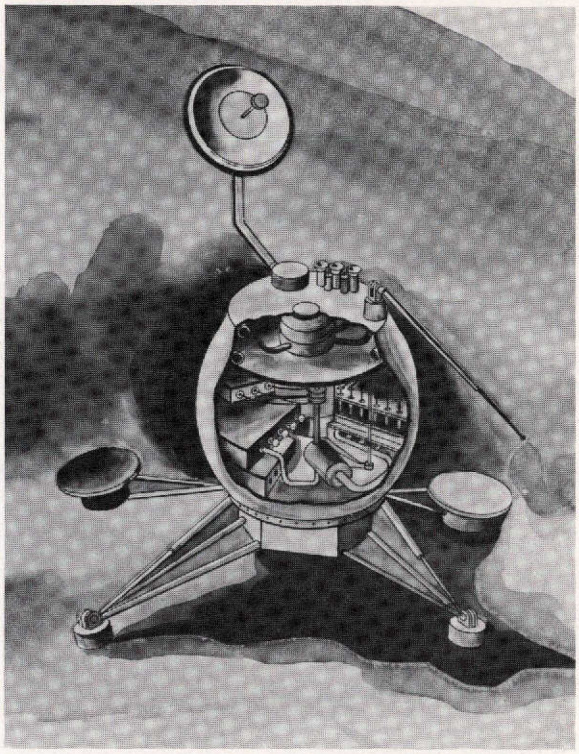
(1) *Biological studies.* These will be accomplished by measuring the biological environment, searching for growth and metabolic activities, seeking organic molecules, making large-scale and microscopic visual examinations, measuring biochemical processes, and seeking deviations from inorganic equilibrium.

(2) *Planetary studies.* These will be accomplished by examining the chemical composition and structure of the surface, searching for water (or evidence of its past existence), measuring the incidence of solar and cosmic radiation, and investigating seismology and radioactivity.

(3) *Atmospheric studies.* These will be accomplished by examining the chemical composition of the atmosphere, temperature, wind velocity and direction, dust flux, surface pressure, and diurnal variations.

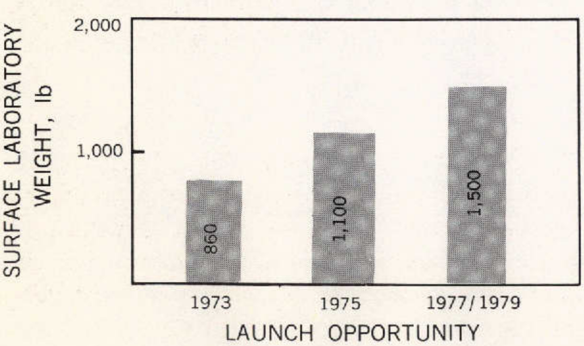
Growth of Martian Surface Laboratory

As the exploration of Mars evolves in the 1970s, major changes in the surface laboratory can be anticipated. The initial surface experiments will concentrate on basic measurements at the landing site. As the bar chart below shows, however, increases are expected in the weight allocated to the surface laboratory. Furthermore, as knowledge of the Martian environment increases, a major growth in experiment sophistication can also be foreseen, including adaptive and reprogrammable control methods, new means for acquiring and processing samples, and mobility on the surface.



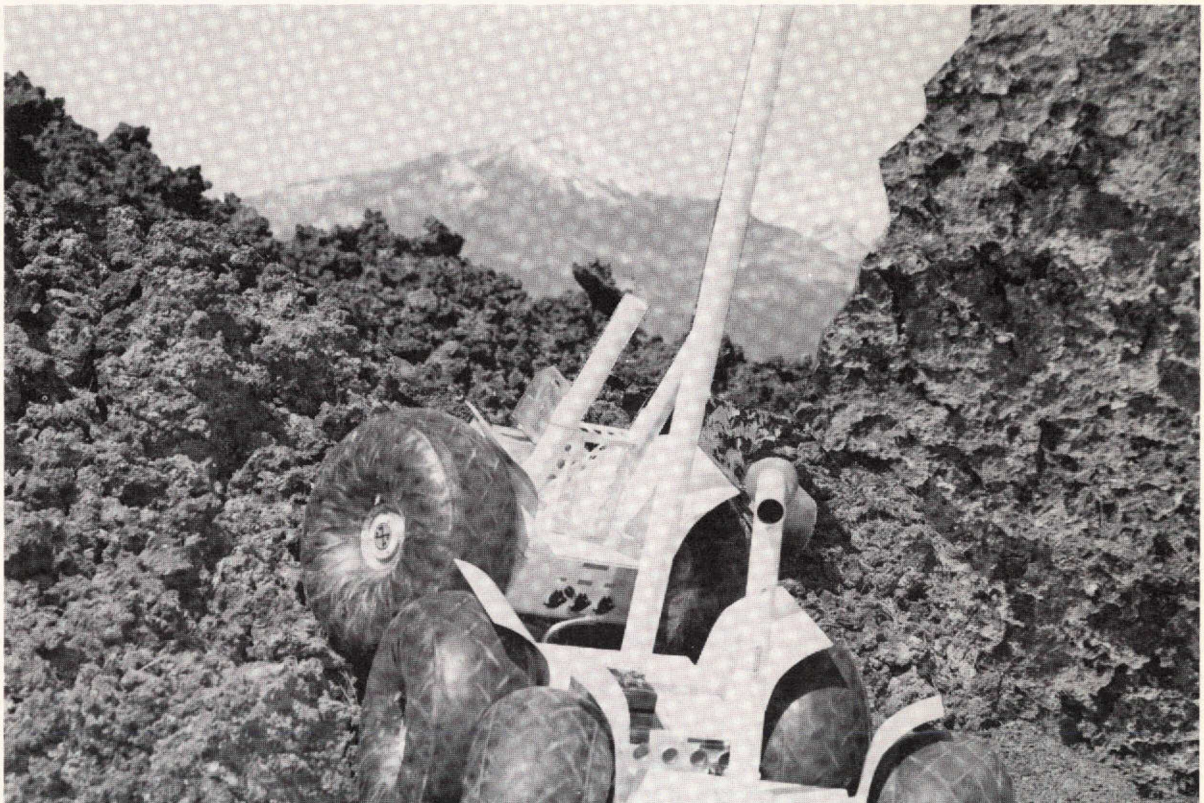
Voyager's surface laboratory system will evolve into a highly automated system that may be similar to that shown. This concept will permit any of a number of experiments to use any part or all of its equipment. Operations will be controlled by an onboard, reprogrammable sequencer. A preplanned sequence of experiments can be changed by means of feedback from previous experiments, by automatic failure detection, or by commands from Earth.

The mission of such a laboratory system would be to detect life, if present; to characterize it chemically and physiologically; to determine its relation to terrestrial life forms, if any; and to aid in establishing the evolutionary path of such life. It would also look for fossil life; and if only fossil life were found, it would examine factors that might have been associated with the extinction of life.



Instruments fitted in the laboratory would include gas chromatographs, mass spectrometers, television cameras, infrared and ultraviolet spectrometers, temperature and pressure transducers, radiation detectors, fluorimeters, weight scales, polarimeters, and numerous reagents. Sample collection and processing mechanisms would provide soil and atmospheric samples; and a radioisotope power supply would be designed for a lifetime of 1 Martian year (2 Earth years), so that seasonal changes could be observed.

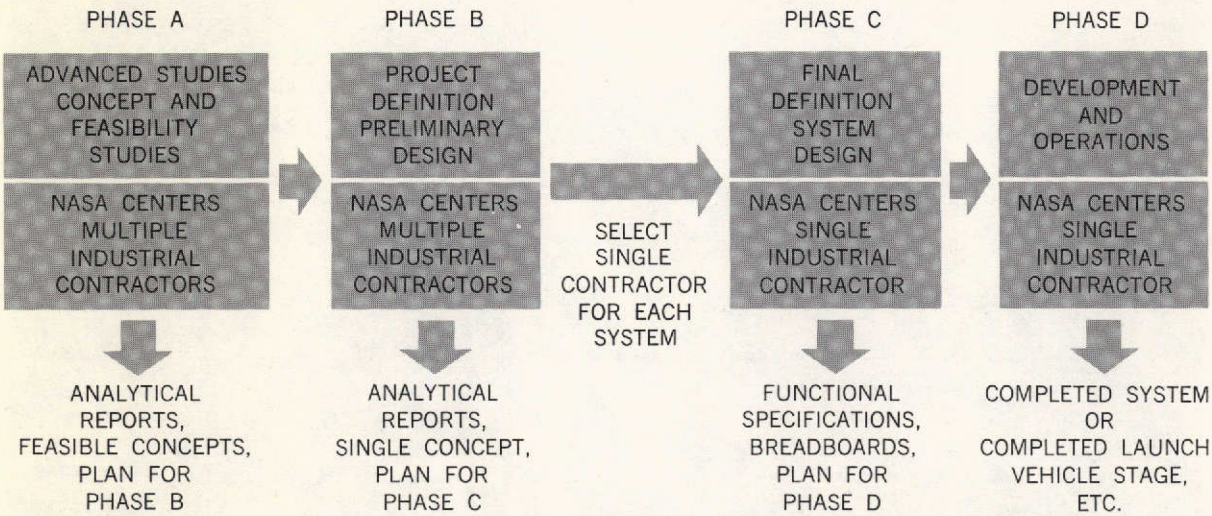
Scientific interplay would be possible between the laboratory on Mars and experimenters on Earth. Experimenters would be supplied with information on the laboratory's status and the progress of experiments. Evaluation of these results could permit decisions to transmit new commands or indeed whole new programs to the laboratory.



A further step in the automated investigation of the planets is the mobile laboratory concept illustrated here. Such a laboratory would have essentially all the capabilities of the stationary automated laboratory, with the additional feature of traveling to locations that are remote from the landing site. By using the television system as an eye, experimenters on Earth could examine the surrounding terrain and direct the laboratory to points of particular scientific interest. This feature would enhance considerably the effectiveness of planetary investigation.

Project Planning and Scheduling

Shown here are the four basic steps in phased project planning as used in the *Voyager* Program. The schedule given outlines the status of the program and its future plans, based upon a first mission during the 1973 Martian opportunity.



***Voyager* schedule: 1973 mission**